US009405292B2

(12) **United States Patent**
Nagasawa

(10) **Patent No.: US 9,405,292 B2**
(45) **Date of Patent: Aug. 2, 2016**

(54) **DELIVERY VEHICLE AND METHOD AND PROGRAM FOR CONTROLLING DRIVE OF DELIVERY VEHICLE**

(71) Applicant: **MURATA MACHINERY, LTD.**, Kyoto-shi, Kyoto (JP)

(72) Inventor: **Atsuo Nagasawa**, Inuyama (JP)

(73) Assignee: **MURATA MACHINERY, LTD.**, Kyoto (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/767,616**

(22) PCT Filed: **Dec. 13, 2013**

(86) PCT No.: **PCT/JP2013/083455**
§ 371 (c)(1),
(2) Date: **Aug. 13, 2015**

(87) PCT Pub. No.: **WO2014/125719**
PCT Pub. Date: **Aug. 21, 2014**

(65) **Prior Publication Data**

US 2016/0004252 A1 Jan. 7, 2016

(30) **Foreign Application Priority Data**

Feb. 15, 2013 (JP) 2013-027727

(51) **Int. Cl.**
G05D 1/00 (2006.01)
G05D 1/02 (2006.01)
G05B 19/418 (2006.01)

(52) **U.S. Cl.**
CPC ***G05D 1/02*** (2013.01); ***G05B 19/41895*** (2013.01); ***G05D 1/0088*** (2013.01); ***G05D 1/021*** (2013.01); *Y02P 90/285* (2015.11)

(58) **Field of Classification Search**
CPC G05B 19/41895; G05D 1/0088; G05D 1/021; Y02P 90/285
USPC 701/23, 26, 50
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,457,964 B1 10/2002 Yamaguchi et al.
6,876,920 B1 * 4/2005 Mailer A01B 69/00 342/457

(Continued)

FOREIGN PATENT DOCUMENTS

JP 2000-099151 A 4/2000
WO 2012/111193 A1 8/2012

OTHER PUBLICATIONS

English translation of Official Communication issued in corresponding International Application PCT/JP2013/083455, mailed on Aug. 27, 2015.

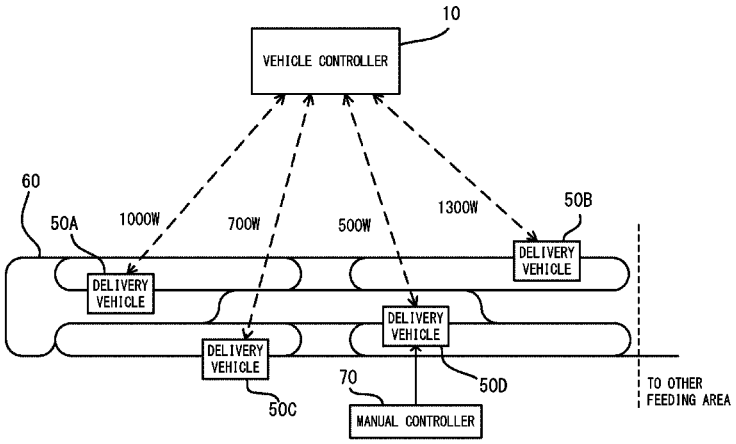
(Continued)

Primary Examiner — Thomas Tarcza
Assistant Examiner — Tyler J Lee
(74) *Attorney, Agent, or Firm* — Keating & Bennett, LLP

(57) **ABSTRACT**

A traveling controller of a delivery vehicle includes a command generator and an acceptable value calculator. The acceptable value calculator calculates a command acceptable value based on a current position of the delivery vehicle. An acceptable value determiner of the command generator determines whether a command position generated by a command position generator exceeds the command acceptable value. When the command position is determined to exceed the command acceptable value, a command position changer of the command generator changes the command position to the command acceptable value.

11 Claims, 12 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

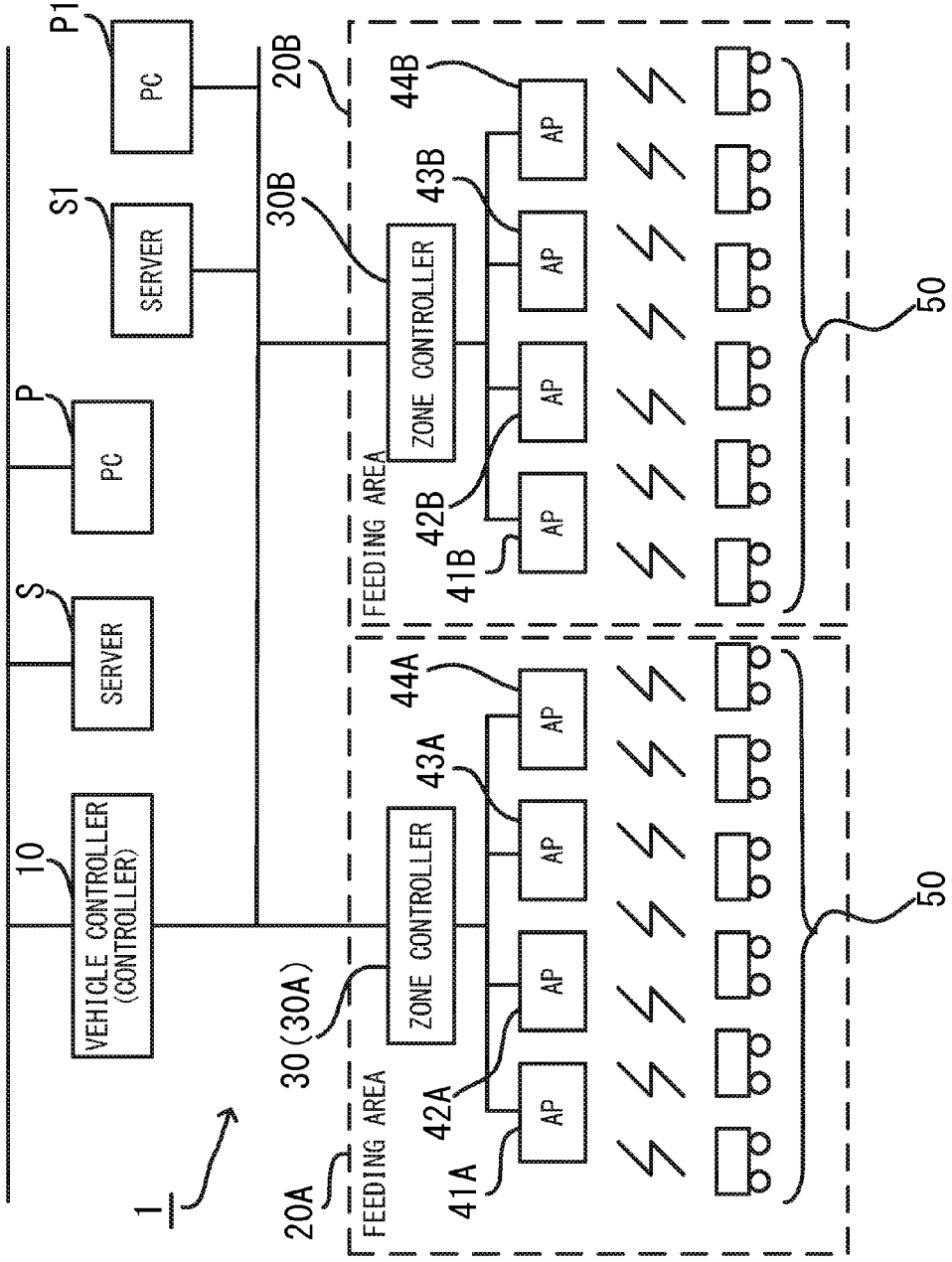
7,574,290	B2 *	8/2009	Gibson	A01B 69/008 177/2
2014/0277897	A1 *	9/2014	Saiz	B60W 10/06 701/23

OTHER PUBLICATIONS

Official Communication issued in International Patent Application No. PCT/JP2013/083455, mailed on Mar. 4, 2014.

* cited by examiner

Fig. 1


1
10
VEHICLE CONTROLLER (CONTROLLER)
S
SERVER
P
PC
S1
SERVER
P1
PC
20A
20B
30 (30A)
30B
FEEDING AREA
FEEDING AREA
ZONE CONTROLLER
ZONE CONTROLLER
41A
42A
43A
44A
41B
42B
43B
44B
AP
50
50

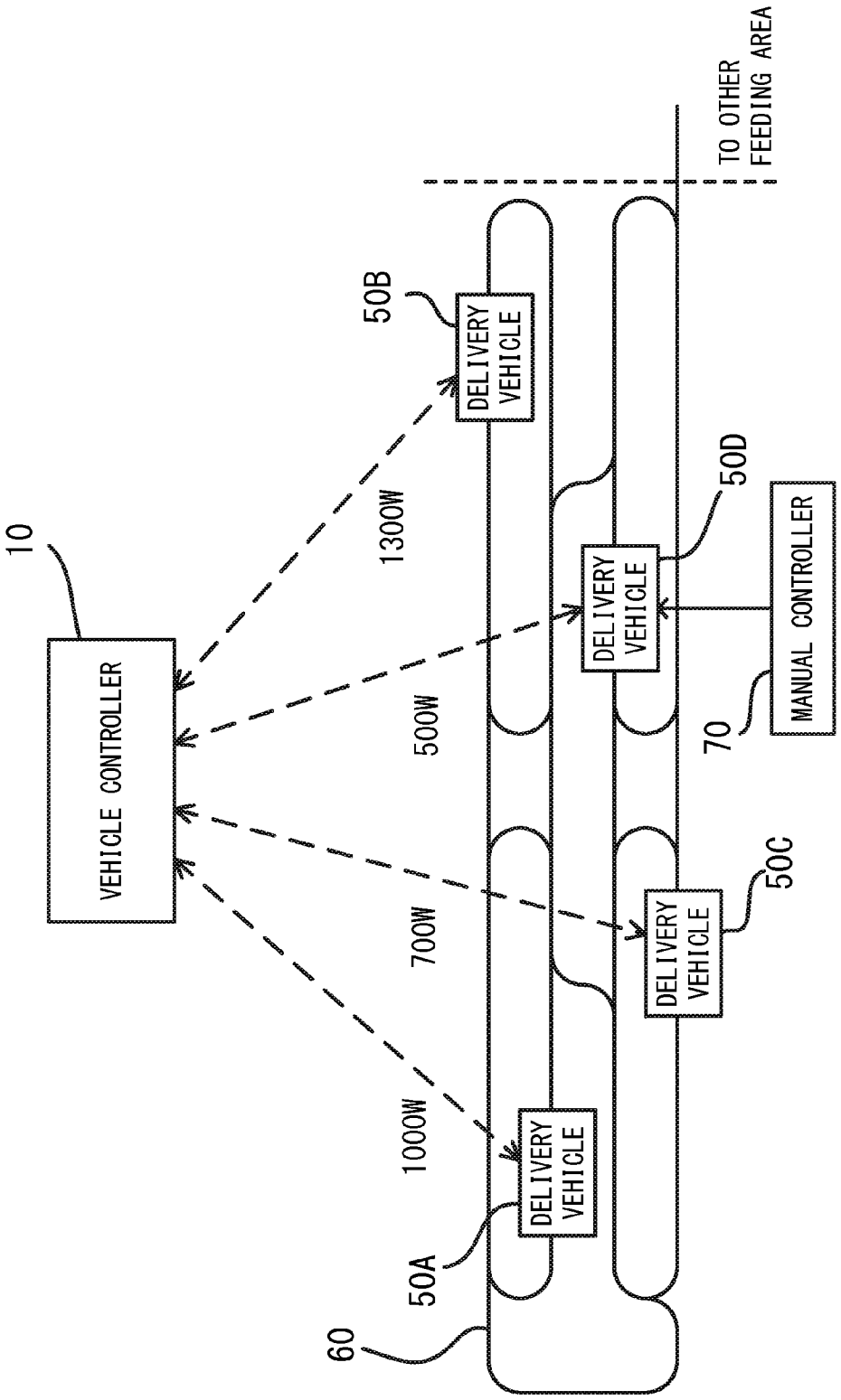

10
VEHICLE CONTROLLER
1300W
500W
700W
1000W
50B
DELIVERY VEHICLE
50D
DELIVERY VEHICLE
50C
DELIVERY VEHICLE
50A
DELIVERY VEHICLE
60
70
MANUAL CONTROLLER
TO OTHER FEEDING AREA

Fig. 2

Fig. 3

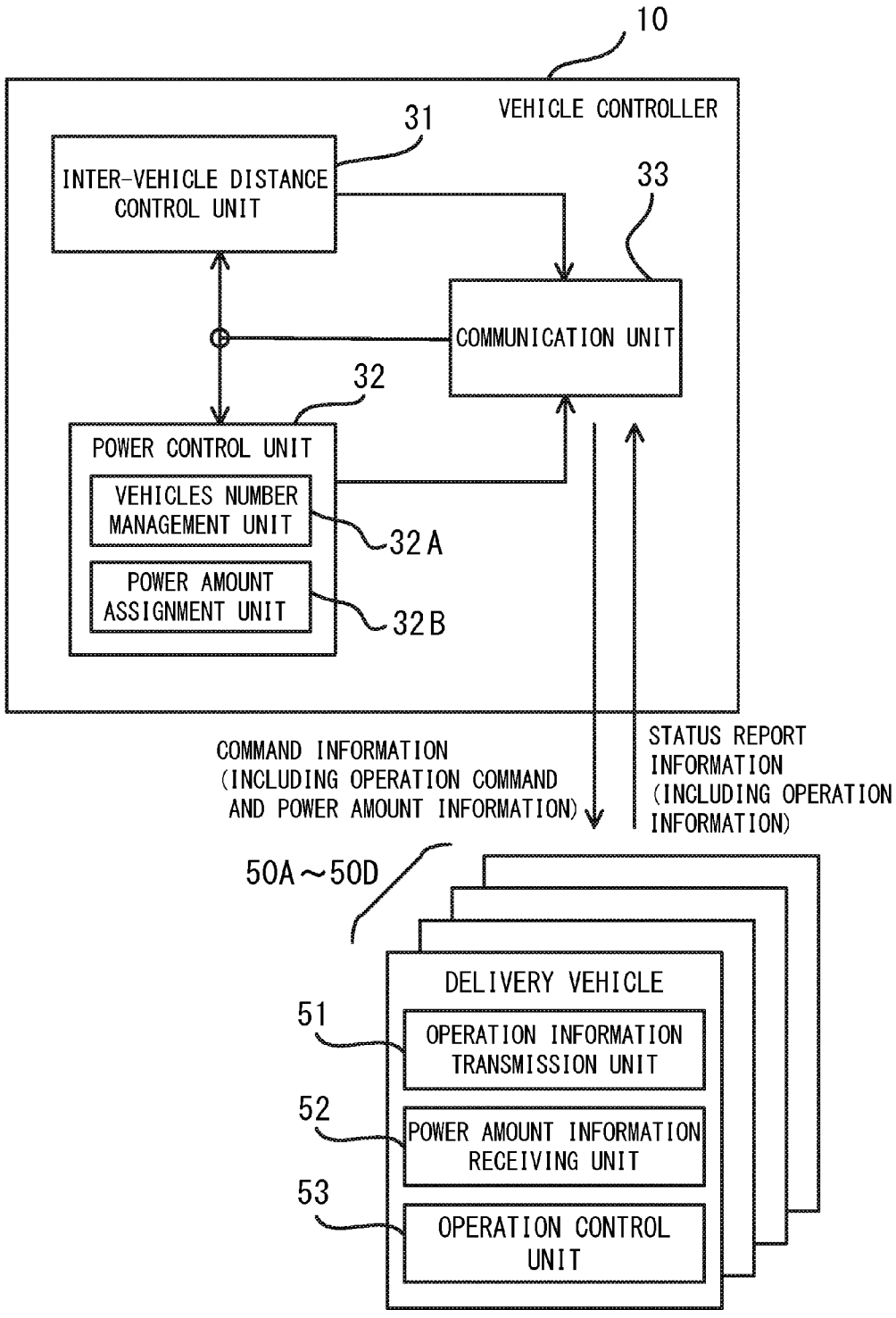

10
VEHICLE CONTROLLER
31
INTER-VEHICLE DISTANCE CONTROL UNIT
33
COMMUNICATION UNIT
32
POWER CONTROL UNIT
VEHICLES NUMBER MANAGEMENT UNIT
32A
POWER AMOUNT ASSIGNMENT UNIT
32B
COMMAND INFORMATION (INCLUDING OPERATION COMMAND AND POWER AMOUNT INFORMATION)
STATUS REPORT INFORMATION (INCLUDING OPERATION INFORMATION)
50A～50D
DELIVERY VEHICLE
51
OPERATION INFORMATION TRANSMISSION UNIT
52
POWER AMOUNT INFORMATION RECEIVING UNIT
53
OPERATION CONTROL UNIT

FIG. 4A COMMAND INFORMATION (CYCLE: 100 ms)

NAME			REMARKS
VEHICLE NO.			2
POWER LIMIT VALUE (POWER AMOUNT INFORMATION)			1300W
OPERATION COMMAND			MOVEMENT/LOADING···
INTER-VEHICLE DISTANCE CONTROL COMMAND	SYSTEM CLOCK		ms
	POSITION	BLOCK	STARTING POINT NO.
		UNIT	DISTANCE FROM STARTING POINT
	SPEED		mm/s
	ATTRIBUTE		

Fig. 4B STATUS REPORT INFORMATION (CYCLE: 100 ms)

NAME		REMARKS
VEHICLE NO.		1～1500
STATUS (OPERATION INFORMATION)		MOVEMENT/LOADING···
CURRENT POSITION	BLOCK	STARTING POINT NO.
	UNIT	DISTANCE FROM STARTING POINT
INTER-VEHICLE DISTANCE INFORMATION	POINT NO. ON ROUTE	
	DISTANCE TO POINT	
	TIME REQUIRED TO REACH POINT	

Fig. 5A MODE

	MODE	DESCRIPTION
1	MANUAL	MODE IN WHICH OPERATOR CAUSES DELIVERY VEHICLE TO JOG BY USING REMOTE CONTROL
2	AUTOMATIC	MODE IN WHICH DELIVERY VEHICLE AUTOMATICALLY MOVES BASED ON COMMAND FROM CONTROLLER ON GROUND
3	SEMI-AUTOMATIC	MODE IN WHICH OPERATOR AUTOMATICALLY MOVES DELIVERY VEHICLE USING VEHICLE CONTROLLER ON GROUND OR REMOTE CONTROL

Fig. 5B STATUS (OPERATION INFORMATION)

	STATUS	MODE	DESCRIPTION
1	ABNORMAL / WARNING	MANUAL /AUTOMATIC /SEMI-AUTOMATIC	RECOVERY FROM ABNORMALITY REQUIRES OPERATOR INTERVENTION. WARNING IS AUTOMATICALLY LIFTED.
2	UNSTARTED	AUTOMATIC /SEMI -AUTOMATIC	VEHICLE IS AT REST AND DOES NOT OPERATE EVEN WHEN RECEIVING COMMAND FROM CONTROLLER ON GROUND
3	IDLE	AUTOMATIC /SEMI -AUTOMATIC	VEHICLE IS AT REST BUT CAN OPERATE UPON RECEIPT OF COMMAND FROM CONTROLLER ON GROUND
4	TRAVELING FOR LOADING	AUTOMATIC /SEMI -AUTOMATIC	VEHICLE IS TRAVELING TO POSITION IN WHICH IT LOADS GOODS
5	TRAVELING FOR UNLOADING	AUTOMATIC /SEMI -AUTOMATIC	VEHICLE IS TRAVELING TO POSITION IN WHICH IT UNLOADS GOODS
6	TRAVELING	AUTOMATIC /SEMI -AUTOMATIC	VEHICLE IS TRAVELING FOR PURPOSE OTHER THAN GOODS TRANSFER, SUCH AS DISPATCH, PUSH-OUT, OR CIRCULATION
7	LOADING	AUTOMATIC /SEMI -AUTOMATIC	VEHICLE IS LOADING GOODS USING TRANSFER APPARATUS
8	UNLOADING	AUTOMATIC /SEMI -AUTOMATIC	VEHICLE IS UNLOADING GOODS USING TRANSFER APPARATUS

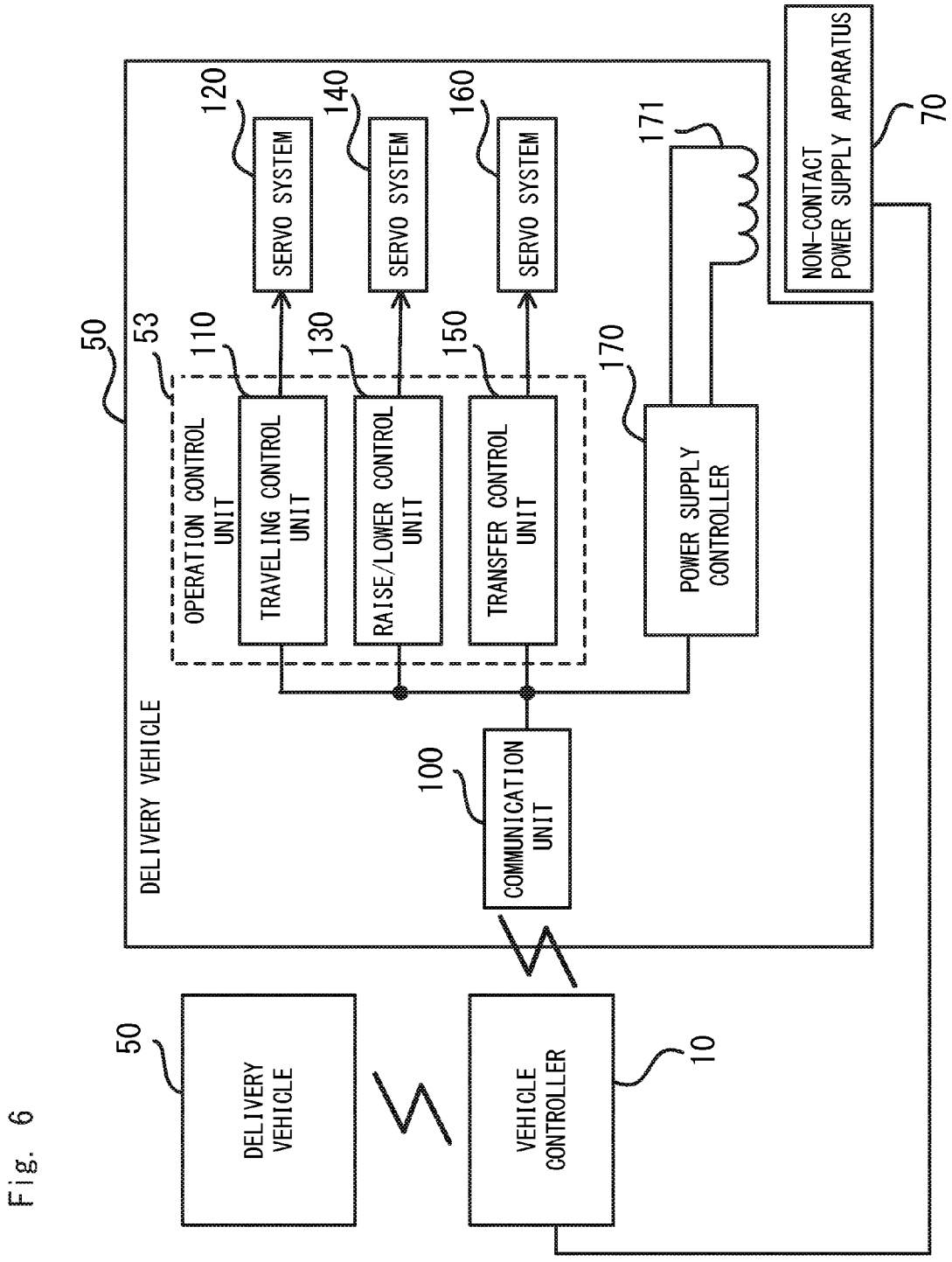
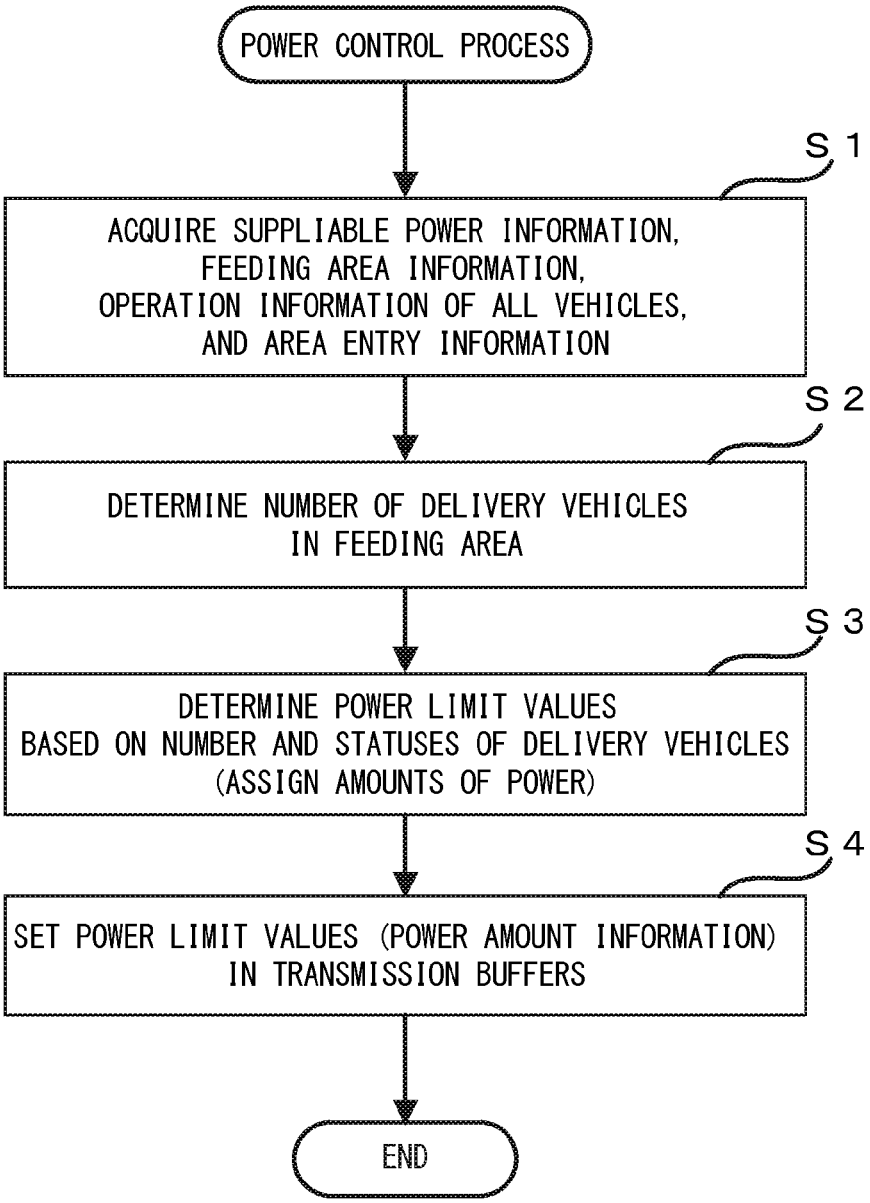

50
DELIVERY VEHICLE
50
DELIVERY VEHICLE
10
VEHICLE CONTROLLER
100
COMMUNICATION UNIT
53
OPERATION CONTROL UNIT
110
TRAVELING CONTROL UNIT
130
RAISE/LOWER CONTROL UNIT
150
TRANSFER CONTROL UNIT
170
POWER SUPPLY CONTROLLER
171
120
SERVO SYSTEM
140
SERVO SYSTEM
160
SERVO SYSTEM
70
NON-CONTACT POWER SUPPLY APPARATUS

Fig. 6

Fig. 7


POWER CONTROL PROCESS
S 1
ACQUIRE SUPPLIABLE POWER INFORMATION,
FEEDING AREA INFORMATION,
OPERATION INFORMATION OF ALL VEHICLES,
AND AREA ENTRY INFORMATION
S 2
DETERMINE NUMBER OF DELIVERY VEHICLES
IN FEEDING AREA
S 3
DETERMINE POWER LIMIT VALUES
BASED ON NUMBER AND STATUSES OF DELIVERY VEHICLES
(ASSIGN AMOUNTS OF POWER)
S 4
SET POWER LIMIT VALUES (POWER AMOUNT INFORMATION)
IN TRANSMISSION BUFFERS
END

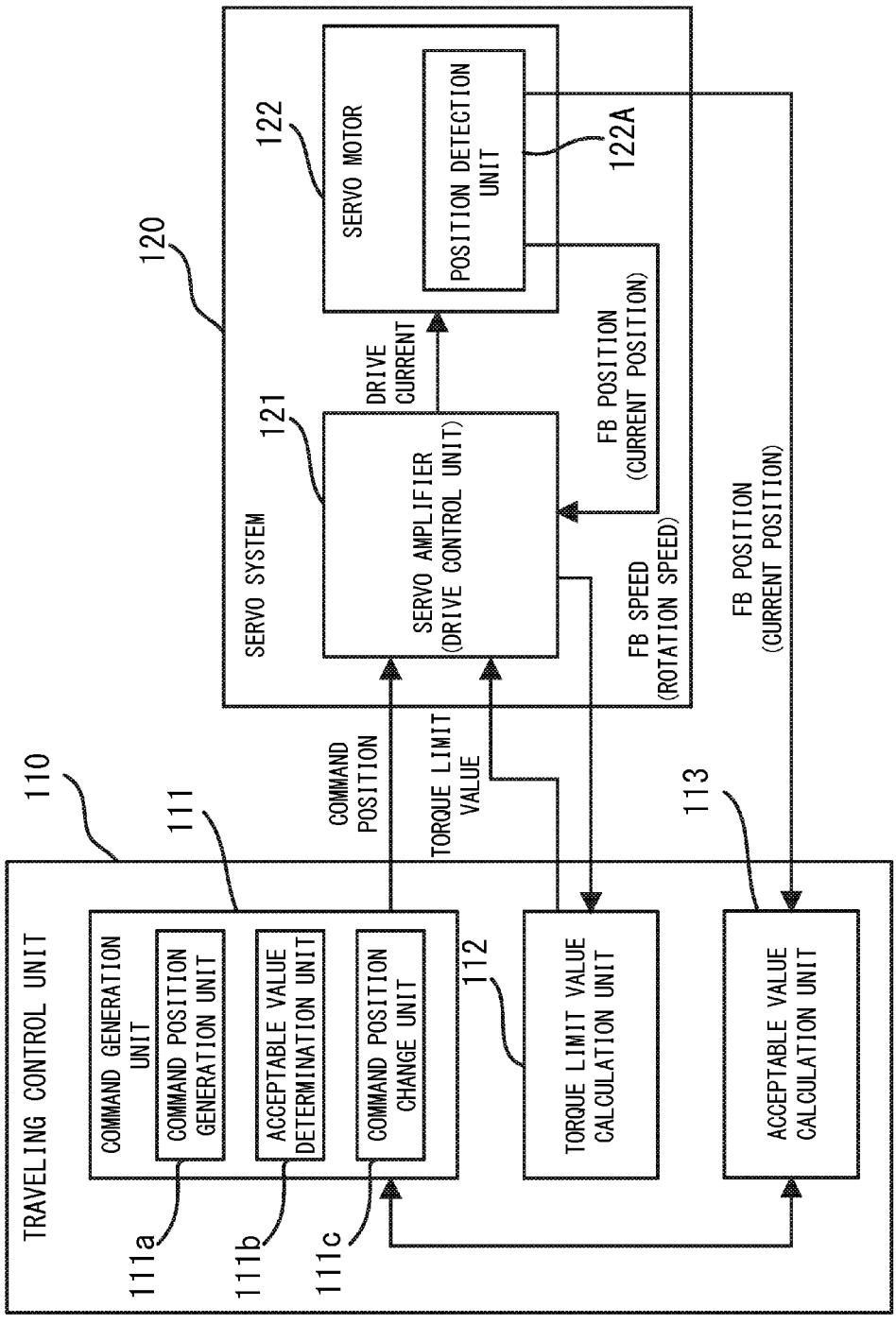

TRAVELING CONTROL UNIT
110
COMMAND GENERATION UNIT
111
COMMAND POSITION GENERATION UNIT
ACCEPTABLE VALUE DETERMINATION UNIT
COMMAND POSITION CHANGE UNIT
112
TORQUE LIMIT VALUE CALCULATION UNIT
113
ACCEPTABLE VALUE CALCULATION UNIT
111a
111b
111c
COMMAND POSITION
TORQUE LIMIT VALUE
SERVO SYSTEM
120
SERVO AMPLIFIER (DRIVE CONTROL UNIT)
121
DRIVE CURRENT
SERVO MOTOR
122
POSITION DETECTION UNIT
122A
FB POSITION (CURRENT POSITION)
FB SPEED (ROTATION SPEED)
FB POSITION (CURRENT POSITION)

Fig. 8

Fig. 9

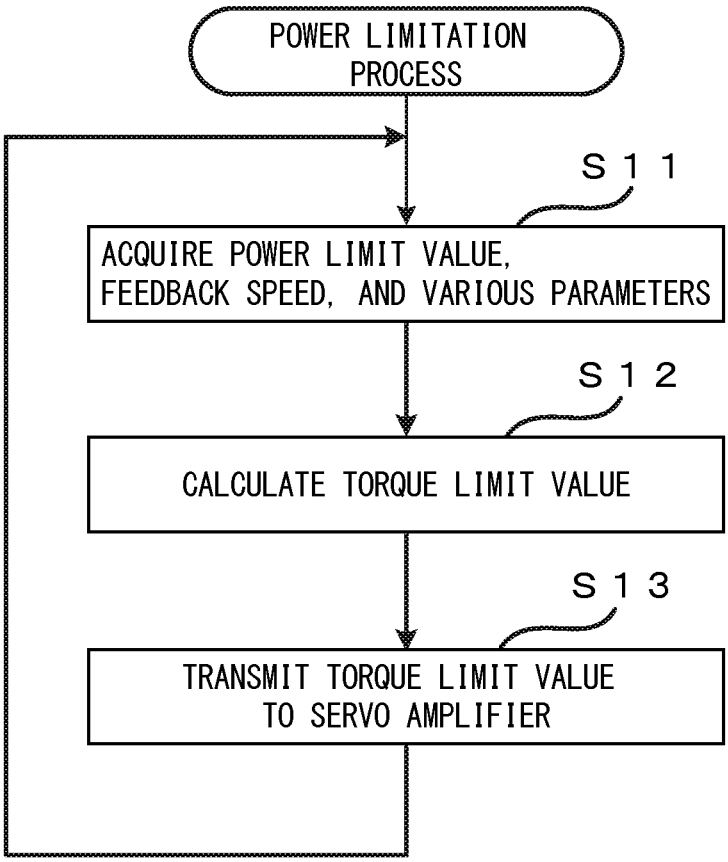

POWER LIMITATION PROCESS
S11
ACQUIRE POWER LIMIT VALUE, FEEDBACK SPEED, AND VARIOUS PARAMETERS
S12
CALCULATE TORQUE LIMIT VALUE
S13
TRANSMIT TORQUE LIMIT VALUE TO SERVO AMPLIFIER

Fig. 10

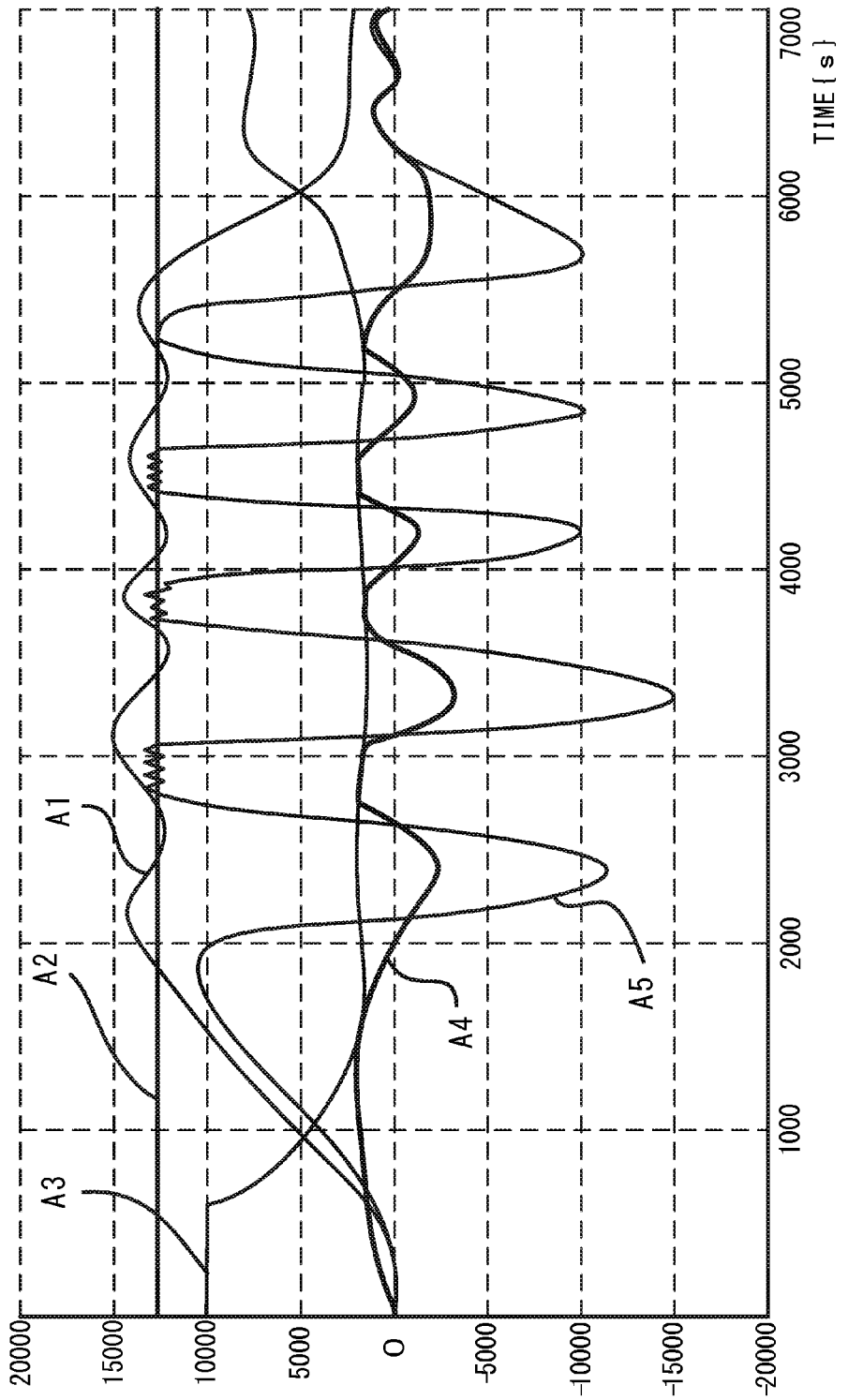

AMOUNT OF POWER [W]
20000
15000
10000
5000
0
-5000
-10000
-15000
-20000
1000
2000
3000
4000
5000
6000
7000
TIME [s]
A1
A2
A3
A4
A5

Fig. 11

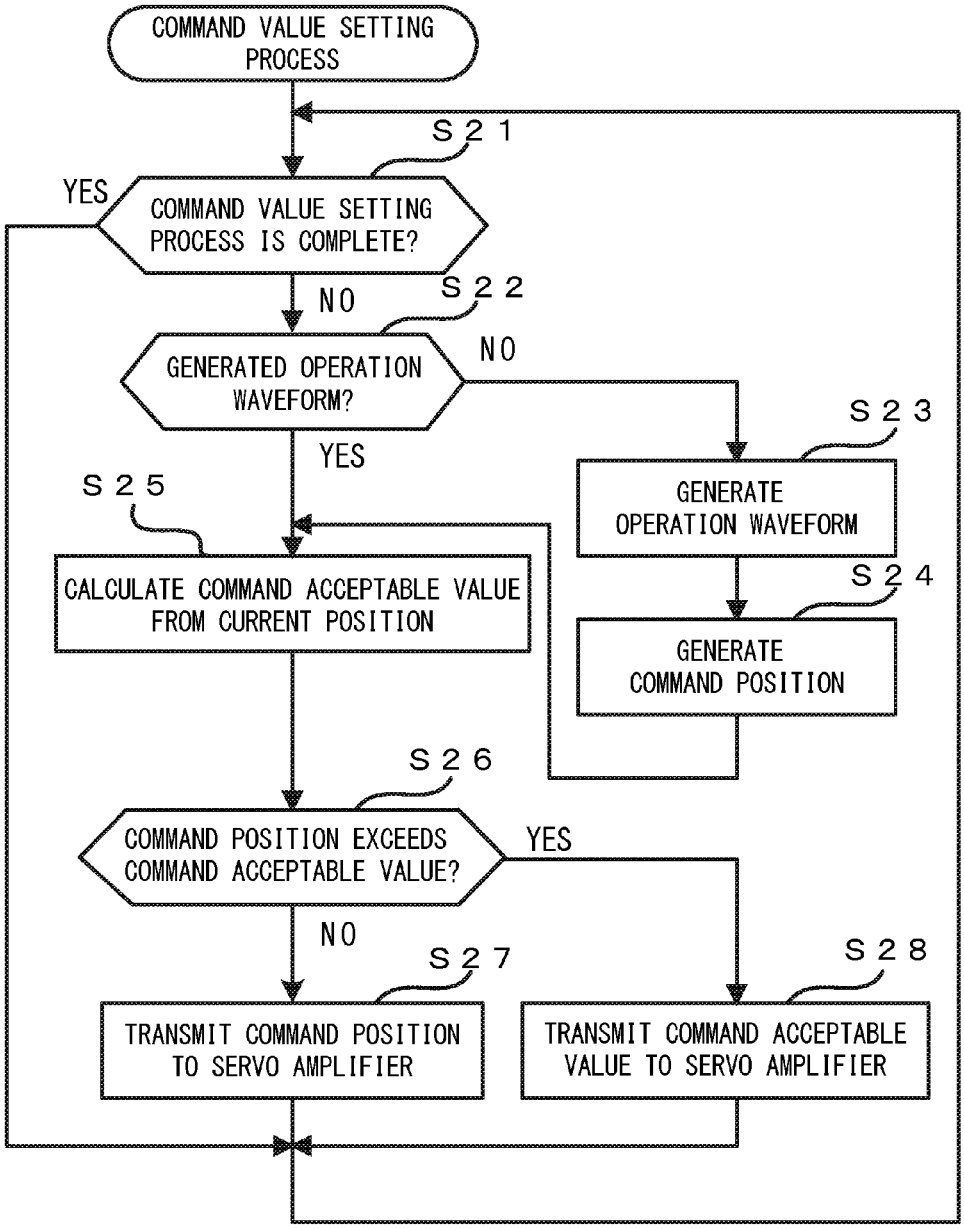
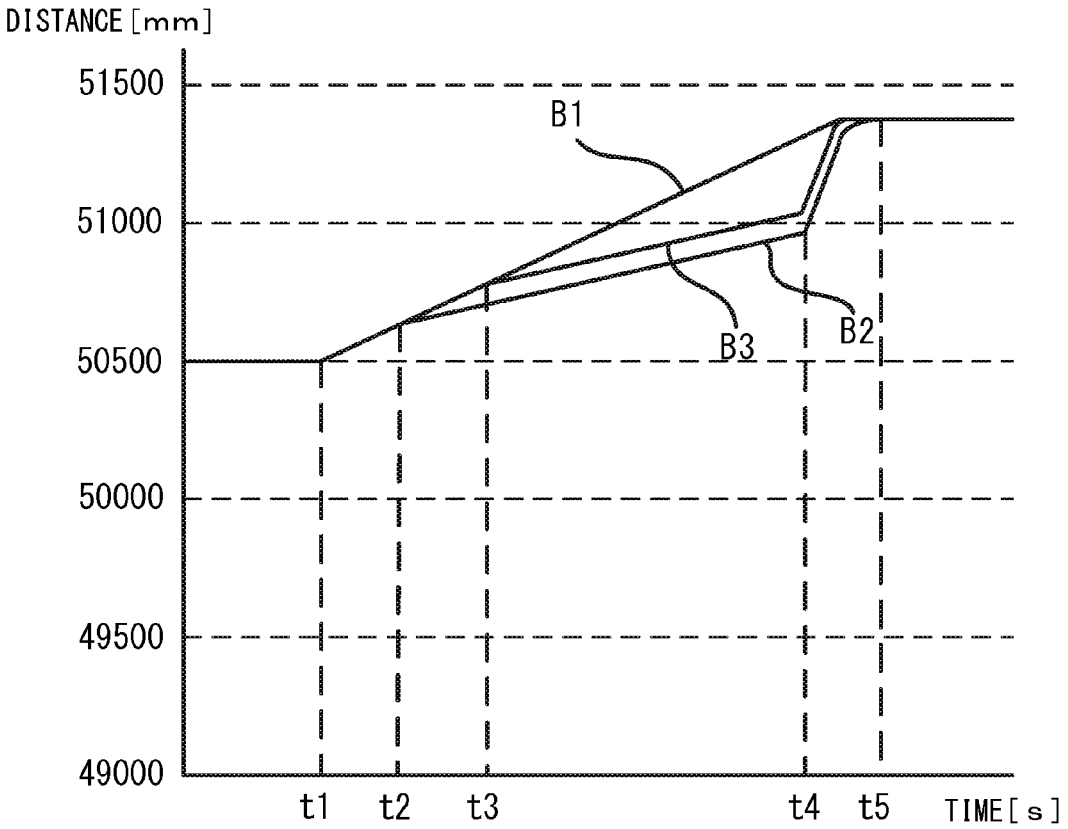

COMMAND VALUE SETTING PROCESS
S21
YES
COMMAND VALUE SETTING PROCESS IS COMPLETE?
NO
S22
GENERATED OPERATION WAVEFORM?
NO
S23
YES
GENERATE OPERATION WAVEFORM
S25
S24
CALCULATE COMMAND ACCEPTABLE VALUE FROM CURRENT POSITION
GENERATE COMMAND POSITION
S26
COMMAND POSITION EXCEEDS COMMAND ACCEPTABLE VALUE?
YES
NO
S27
S28
TRANSMIT COMMAND POSITION TO SERVO AMPLIFIER
TRANSMIT COMMAND ACCEPTABLE VALUE TO SERVO AMPLIFIER

Fig. 12


DISTANCE [mm]
51500
51000
50500
50000
49500
49000
B1
B2
B3
t1
t2
t3
t4
t5
TIME [s]

DELIVERY VEHICLE AND METHOD AND PROGRAM FOR CONTROLLING DRIVE OF DELIVERY VEHICLE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a delivery vehicle that is moved by driving a servomotor, and a method and program to control driving of a delivery vehicle.

2. Description of the Related Art

There have been known vehicle control systems that automatically deliver goods using delivery vehicles, for example, in a factory or warehouse. In such a system, each delivery vehicle is driven by a servomechanism including a servomotor. The servomechanism includes a controller, a servo amplifier, and a servomotor. The servo amplifier drives the servomotor by supplying, to the servomotor, a drive current corresponding to the difference between the command position from the controller and the current position from a position detector in the servomotor. Japanese Unexamined Patent Application Publication No. 2000-99151 discloses, as such a system, a configuration in which the gain for feedback control varies with the weight of a loaded article.

When unexpected disturbance or the like occurs, the servomechanism may abruptly change the drive of the servomotor so that the current position follows the command position. However, such a transient movement for following the command position cannot be controlled by the controller. For this reason, the current position may significantly deviate from the command position due to the unexpected disturbance or the like, failing to follow the command position. Further, the servomechanism may raise the output torque in order to follow the command position, thereby increasing power consumption. Furthermore, such an excessive movement may impair safety. While the system of Japanese Unexamined Patent Application Publication No. 2000-99151 described above performs feedback control using an appropriate gain corresponding to the weight of a loaded article, the system does not have any means for avoiding the current position from excessively deviating from the command position.

SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a delivery vehicle that prevents a current position from deviating from a command position due to unexpected disturbance or the like, and a method and program to control driving of a delivery vehicle.

According to a preferred embodiment of the present invention, a delivery vehicle includes a command position generator that generates a command position to move the delivery vehicle to a target position by driving a servomotor, an acceptable value calculator that calculates a predetermined acceptable value based on a current position, an acceptable value determiner that determines whether the command position exceeds the predetermined acceptable value calculated by the acceptable value calculator, and a command position changer that changes the command position when the acceptable value determiner determines that the command position exceeds the predetermined acceptable value.

The delivery vehicle may further include a position detector configured to detect the current position, and the acceptable value calculator may calculate the predetermined acceptable value based on the current position outputted from the position detector. Further, the command position changer may change the command position to the predetermined acceptable value or a predetermined position within a range which does not exceed the predetermined acceptable value. Further, the command position generator may generate the command position in predetermined cycles, and the acceptable value calculator may acquire the current position in synchronization with generation of the command position. Further, preferably, the predetermined acceptable value is set to include the amount of movement during one of the predetermined cycles. Further, the command position changer may change the command position at the timing when the command position generator generates the command position.

Another preferred embodiment of the present invention provides a method to control driving of a delivery vehicle. The method includes generating a command position to move the delivery vehicle to a target position by driving a servomotor, calculating a predetermined acceptable value based on a current position; determining whether the command position exceeds the predetermined acceptable value, and changing the command position when it is determined that the command position exceeds the predetermined acceptable value.

A further preferred embodiment of the present invention provides a non-transitory computer-readable medium including a computer program that controls driving of a delivery vehicle. The program causes the delivery vehicle to perform a command position generation process of generating a command position to move the delivery vehicle to a target position by driving a servomotor, an acceptable value calculation process of calculating a predetermined acceptable value based on a current position, an acceptable value determination process of determining whether the command position exceeds the predetermined acceptable value calculated in the acceptable value calculation process, and a command position change process of changing the command position when it is determined in the acceptable value determination process that the command position exceeds the predetermined acceptable value.

According to various preferred embodiments of the present invention, a predetermined acceptable value is calculated based on the current position; it is determined whether the command position exceeds the predetermined acceptable value; when it is determined that the command position exceeds the predetermined acceptable value, the command position is changed. Thus, it is possible to prevent the current position from deviating from the command position due to unexpected disturbance or the like. As a result, the following are prevented: a significant deviation of the current position from the command position and thus a failure to follow the command position; raising of the output torque to follow the command position and thus an increase in power consumption; and impairment of safety due to an excessive movement.

Further, if the delivery vehicle includes a position detector configured to detect the current position and the acceptable value calculator calculates the predetermined acceptable value based on the current position outputted from the position detector, it is possible to calculate an acceptable value based on the correct current position. Further, if the command position changer changes the command position to the predetermined acceptable value or to a predetermined position within a range which does not exceed the predetermined acceptable value, it is possible to set the command position to an acceptable value corresponding to the configuration or use configuration of the servomechanism, or the like. Further, if the command position generator generates the command position in predetermined cycles and the acceptable value calculator acquires the current position in synchronization with the generation of the command position, it is possible to calculate an acceptable value based on a position close to the

actual current position. Further, if the predetermined acceptable value is set to include the amount of movement during one of the predetermined cycles, it is possible to set an accurate acceptable value. Further, if the command position changer changes the command position at the timing when the command position generator generates the command position, it is possible to prevent a delay in changing the command position and to control the drive of the servomotor based on the changed command position.

The above and other elements, features, steps, characteristics and advantages of the present invention will become more apparent from the following detailed description of the preferred embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a system configuration diagram of a delivery vehicle control system according to an example preferred embodiment of the present invention.

FIG. **2** is a schematic diagram showing the configuration in one feeding area, of the vehicle control system shown in FIG. **1**.

FIG. **3** is a block diagram showing the configuration of a vehicle controller shown in FIG. **1**.

FIGS. **4**A and **4**B are diagrams showing command information or status report information exchanged between the vehicle controller and delivery vehicles, in which FIG. **4**A is a diagram showing command information; and FIG. **4**B is a diagram showing status report information.

FIGS. **5**A and **5**B includes diagrams showing the modes or statuses of a delivery vehicle.

FIG. **6** is a block diagram showing the configuration of a delivery vehicle shown in FIG. **1**.

FIG. **7** is a flowchart showing an example of a power control process performed by the vehicle controller.

FIG. **8** is a block diagram showing the configurations of a traveling controller and a servo system.

FIG. **9** is a flowchart showing an example of a power limitation process performed by the traveling controller.

FIG. **10** is a waveform diagram showing the relationships among the power consumption, speed, torque, and torque limit value of a servomotor.

FIG. **11** is a flowchart showing an example of a command value setting process performed by the traveling controller.

FIG. **12** is a diagram showing waveforms of the unchanged command position, current position, and changed command position.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereafter, preferred embodiments of the present invention will be described with reference to the drawings.

FIG. **1** is a system configuration diagram a vehicle control system according to an example preferred embodiment of the present invention. As shown in FIG. **1**, a vehicle control system **1** is a system in which multiple delivery vehicles **50** perform predetermined operations based on operation commands transmitted from a vehicle controller (controller) **10**. The vehicle control system **1** includes at least multiple zone controllers **30** installed on the ground and the multiple delivery vehicles **50**. If the area in which the delivery vehicles **50** are able to move is divided into multiple areas, the divided areas are provided with zone controllers **30**A and **30**B, respectively, in the vehicle control system **1**.

In the example shown in FIG. **1**, the vehicle controller **10** is connected to another server S and a personal computer P through a local area network (LAN). The vehicle controller **10** is also connected to the two zone controllers, **30**A and **30**B, through the LAN, as well as to a server S**1** and a personal computer P**1** through the LAN. The zone controller **30**A is connected to multiple access points **41**A to **44**A (represented by "AP" in FIG. **1**) through the LAN, and the zone controller **30**B is connected to multiple access points **41**B to **44**B (represented by "AP" in FIG. **1**) through the LAN. The access points **41**A to **44**A and **41**B to **44**B communicate with the multiple delivery vehicles **50** through a wireless LAN, for example.

The vehicle controller **10** is a computer server that centrally controls the vehicle control system **1**. Specifically, when the vehicle controller **10** receives a request to deliver a predetermined article from the other server S, personal computer P, or the like, the vehicle controller **10** transmits, to one of the delivery vehicles **50**, delivery instruction information corresponding to the delivery request and instructing the delivery vehicle **50** to deliver the predetermined article. For example, the delivery instruction includes information on which delivery vehicle **50** being used to deliver the predetermined article, the position in which the predetermined article is to be loaded, the position in which the predetermined article is to be unloaded, and the route of the delivery vehicle **50** (movement path). At this time, the vehicle controller **10** properly determines a route that bypasses the concentration or congestion of the delivery vehicles **50** while avoiding the delivery vehicle **50** from being interfered with the other delivery vehicles **50**.

As shown in FIG. **1**, the area in which the delivery vehicles **50** are able to move is divided into multiple areas. The multiple areas are feeding areas **20**A and **20**B, and are provided with the zone controllers **30**A and **30**B, respectively. The feeding areas **20**A and **20**B are each assigned the amount of power corresponding to the size of the area, the workloads of the delivery vehicles **50** in the area, and the like. The amount of power assigned to each of the feeding areas **20**A and **20**B serves as the main amount of power of the feeding area. The respective main amounts of power are determined by the vehicle controller **10**. For example, the vehicle controller **10** assigns the main amount of power of 3500 W to the feeding area **20**A and the main amount of power of 4000 W to the feeding area **20**B.

In causing a delivery vehicle **50** in one feeding area (e.g., feeding area **20**B) to enter other feeding area (e.g., feeding area **20**A), the vehicle controller **10** transmits area entry information to the zone controller **30** in the feeding area which the delivery vehicle **50** is to enter. The area entry information includes information identifying the delivery vehicle **50** which is to enter the feeding area **20**A (e.g., vehicle number information) and information indicating the operating status (status) of the delivery vehicle **50**.

The zone controllers **30**A and **30**B perform collision prevention control (blocking control) of the delivery vehicles **50** in the feeding area **20**A and **20**B, respectively. As shown in FIG. **1**, the zone controller **30**A is installed on the ground in the feeding area **20**A. The zone controller **30**A performs blocking control of the delivery vehicles **50** in the feeding area **20**A by wirelessly communicating with the delivery vehicles **50** in the feeding area **20**A through the access points **41**A to **44**A. The zone controller **30**B is installed on the ground in the feeding area **20**B. The zone controller **30**B performs blocking control of the delivery vehicles **50** in the feeding area **20**B by wirelessly communicating with the delivery vehicles **50** in the feeding area **20**B through the access points **41**B to **44**B. Note that there may be used a

configuration in which the zone controllers **30**A and **30**B are omitted and the vehicle controller **10** performs blocking control.

The delivery vehicles **50** are, for example, ceiling traveling vehicles, which travel along rails installed on the ceiling. However, the delivery vehicles **50** are not limited to ceiling traveling vehicles and may be, for example, delivery vehicles which do not include one or both of lifting and transfer apparatuses, stacker cranes, or the like.

If the area in which the delivery vehicles **50** are able to move is not divided into multiple areas (that is, if there is only one feeding area), one zone controller **30** may perform control such as the reception of a delivery request, the determination of a task corresponding to the delivery request, and the determination of the route of the delivery vehicle **50**, or there may be used a configuration in which the zone controller **30** is omitted and the vehicle controller **10** performs control of the vehicles, including blocking control. Further, even if the area in which the delivery vehicles **50** are able to move is divided into multiple feeding areas, **20**A and **20**B, the zone controllers **30** may perform some or all functions of the vehicle controller **10**. Further, the area in which the delivery vehicles **50** are able to move may be divided into three or more feeding areas, for example. In this case, a zone controller may be installed in each feeding area.

FIG. **2** is a schematic diagram showing the configuration in one feeding area, of the vehicle control system shown in FIG. **1**. Specifically, FIG. **2** shows the configuration in the feeding area **20**A thereof. In FIG. **2**, the zone controller **30**A and access points **41**A to **44**A are omitted, and four delivery vehicles **50**A to **50**D are able to enter the feeding area **20**A.

As shown in FIG. **2**, a rail (track) **60** on which the delivery vehicles **50**A to **50**D travel is installed along the load ports of multiple production facilities or the like in the feeding area **20**A. The rail **60** is connected to a rail installed in the other feeding area, **20**B.

In the example shown in FIG. **2**, the delivery vehicle **50**A is automatically circulating (traveling); the delivery vehicle **50**B is automatically traveling to an unloading position; the delivery vehicle **50**C is automatically transferring (loading) an article; and the delivery vehicle **50**D is jogging manually (based on an operation of a manual controller **70** such as a remote control by the operator).

In the present preferred embodiment, the vehicle controller **10** determines the maximum amounts of power consumption to be assigned to each delivery vehicles **50**A to **50**D corresponding to the operating statuses of the delivery vehicles **50**A to **50**D within the main amount of power that is supplied to the feeding area **20**A. The maximum amounts of power consumption are the amounts of power available (consumable) to the delivery vehicles **50**A to **50**D, respectively, in the main amount of power assigned to the feeding area **20**A.

In the example shown in FIG. **2**, the delivery vehicle **50**A, which is automatically circulating, is assigned the amount of power of 1000 W as the maximum amount of power consumption; the delivery vehicle **50**B, which is automatically traveling to the unloading position, is assigned the amount of power of 1300 W as the maximum amount of power consumption; the delivery vehicle **50**C, which is automatically transferring the article, is assigned the amount of power of 700 W as the maximum amount of power consumption; and the delivery vehicle **50**D, which is manually jogging, is assigned the amount of power of 500 W as the maximum amount of power consumption. The delivery vehicles **50**A to **50**D perform operations such as traveling within the assigned maximum amounts of power consumption, respectively.

Although the configuration in the feeding area **20**B is not shown in FIG. **2**, it is the same as that in the feeding area **20**A except for the number of delivery vehicles, the position of the rail, and the like. For this reason, repeated description is omitted.

FIG. **3** is a block diagram showing the configuration of the vehicle controller shown in FIG. **1**. FIGS. **4**A and **4**B are diagrams showing command information or status report information exchanged between the vehicle controller and the delivery vehicles, in which FIG. **4**A is a diagram showing command information; and FIG. **4**B is a diagram showing status report information. The elements shown in FIG. **3** are implemented when an arithmetic device such as a central processor (CPU) performs processing in accordance with a program stored in the memory.

As shown in FIG. **3**, the vehicle controller **10** includes an inter-vehicle distance controller **31**, a power controller **32**, and a communicator **33**. The inter-vehicle distance controller **31** is a processor that commands the operations of the delivery vehicles **50**A to **50**D in the feeding area **20**A and/or inter-vehicle distances of the delivery vehicles **50**A to **50**B. Specifically, the inter-vehicle distance controller **31** recognizes the operations of the delivery vehicles **50**A to **50**D in the feeding area **20**A and the routes of the delivery vehicles **50**A to **50**D based on delivery command information. The inter-vehicle distance controller **31** also recognizes the current positions of the delivery vehicles **50**A to **50**D on the routes in the feeding area **20**A and the current distances between these delivery vehicles based on status report information transmitted from these delivery vehicles **50**A to **50**D as seen in FIG. **4**B. The inter-vehicle distance controller **31** then outputs, to the communicator **33**, command information commanding the delivery vehicles **50**A to **50**D in the feeding area **20**A to perform operations or keep inter-vehicle distances as seen in FIG. **4**A.

The command information outputted from the inter-vehicle distance controller **31** preferably includes vehicle number information identifying a delivery vehicle ("vehicle No." in FIG. **4**A), operation command information commanding the delivery vehicle to perform an operation (e.g., traveling, loading, or the like) ("operation command" in FIG. **4**A), and inter-vehicle distance control command information commanding the delivery vehicle to control inter-vehicle distances ("inter-vehicle distance control command" in FIG. **4**A). The inter-vehicle distance control command information includes "system clock (millisecond)," "block (starting point No.)" identifying the target position, "unit (distance from starting point)," "speed (mm/s)," and "attribute."

The information, for which the inter-vehicle distance controller **31** recognize the current positions of the delivery vehicles **50**A to **50**D and the current inter-vehicle distances, are vehicle number information identifying a vehicle (e.g., "1 to 1500"), current position information ("current position" in FIG. **4**B) including "block (starting point No.)" identifying the current position of the delivery vehicle and "unit (distance from starting point)," and inter-vehicle distance information consisting of "point No. on route" "distance to point" and "time required to reach point" among the status report information shown in FIG. **4**B.

The power controller **32** is a processor that manages the number of the delivery vehicles **50** in the feeding area **20**A and determines the maximum amounts of power consumption assigned to the respective delivery vehicles **50** in the feeding area **20**A. As shown in FIG. **3**, the power controller **32** includes a vehicles number controller **32**A and a power amount assigner **32**B. The vehicles number controller **32**A determines whether to permit delivery vehicles **50** to enter the

feeding area **20**A and also determines the number of delivery vehicles **50** that perform operations such as traveling in the feeding area **20**A. The power amount assigner **32**B determines the maximum amounts of power consumption corresponding to the number of delivery vehicles **50** in the feeding area **20**A determined by the vehicles number controller **32**A and the current operating statuses (statuses) of delivery vehicles **50**, and assigns the determined maximum amounts of power consumption to the respective delivery vehicles **50**.

Specifically, the power controller **32** recognizes the main amount of power that is able to be supplied to the feeding area **20**A, based on feeding area information and suppliable power information. The power controller **32** also recognizes the current statuses (statuses) of the delivery vehicles **50**A to **50**D in the feeding area **20**A based on the status report information, shown in FIG. **4**B, transmitted from the delivery vehicles **50**A to **50**D. The power controller **32** also recognizes whether there are any delivery vehicles which are newly entering the feeding area **20**A, based on the area entry information.

More specifically, the information, for which the power controller **32** recognizes the operating status of each of the delivery vehicles **50**A to **50**D, are vehicle number information identifying the delivery vehicle (e.g., "1 to 1500") and status information ("operation information") indicating the operating status of the delivery vehicle among the status report information shown in FIG. **4**B.

The vehicles number controller **32**A of the power controller **32** determines the number of the delivery vehicles in the feeding area **20**A based on the main amount of power, the statuses of the delivery vehicles **50** (if there are any newly entering delivery vehicles, the statuses of those delivery vehicles), the number of the delivery vehicles **50** in the feeding area **20**A, and information indicating whether there are any delivery vehicles entering the feeding area **20**A. The power amount assigner **32**B of the power controller **32** determines the maximum amounts of power consumption assigned to the respective delivery vehicles **50** within the main amount of power based on the number of delivery vehicles **50** in the feeding area **20**A determined by the vehicles number controller **32**A and the current operating statuses (statuses) of the delivery vehicles **50**. The power amount assigner **32**B of the power controller **32** then outputs power amount information indicating each determined maximum amount of power consumption to the communicator **33**.

The power amount information indicating the maximum amount of power consumption outputted from the power controller **32** is "power limit value" in the command information shown in FIG. **4**A.

The communicator **33** is a processor that transmits or receives information to or from the delivery vehicles **50**A to **50**D in communication cycles of, for example, 100 ms. Specifically, the communicator **33** sets, in a transmission buffer, command information outputted from the inter-vehicle distance controller **31** and commanding each delivery vehicle to perform an operation or keep inter-vehicle distances, that is, the vehicle number information, operation command information, and inter-vehicle distance control information in the command information shown in FIG. **4**A. The communicator **33** also sets, in the transmission buffer, the power amount information outputted from the power controller **32** ("power limit value" in the command information shown in FIG. **4**A). The communicator **33** then transmits the buffered command information to the delivery vehicles **50**A to **50**D in synchronization with in communication cycles of 100 ms.

As shown in FIG. **3**, the delivery vehicles **50**A to **50**D each include an operation information transmitter **51** that transmits operation information to the vehicle controller **10**, a power amount information receiver **52** that receives power amount information transmitted from the vehicle controller **10**, and an operation controller **53** that performs an operation within the amount of power assigned by the power amount assigner **32**B.

Next, specific examples of the status (operating status) will be described. FIGS. **5**A and **5**B are diagrams showing the modes and statuses of a delivery vehicle. In the present preferred embodiment, as shown in FIG. **5**A, a delivery vehicle **50** has three modes: "manual," "automatic," and "semi-automatic." "Manual" is a mode in which the operator causes the delivery vehicle **50** to jog by using a remote control (manual controller **70**) near the delivery vehicle **50**. "Automatic" is a mode in which the delivery vehicle **50** automatically moves based on a command from the vehicle controller **10**. "Semi-automatic" is a mode in which the operator automatically moves the delivery vehicle **50** using the vehicle controller **10** or remote control.

Further, in the present preferred embodiment, as shown in FIG. **5**B, the delivery vehicle **50** preferably has eight statuses, for example: "abnormal/warning," "unstarted," "idle," "traveling for loading," "traveling for unloading," "traveling," "loading," and "unloading." "Abnormal/warning" is a status in which an abnormality is occurring and a warning is needed. "Unstarted" is a status in which the delivery vehicle **50** is yet to be started. "Idle" is a status in which the delivery vehicle **50** is at rest but can perform an operation upon receipt of a command from the vehicle controller **10**. "Traveling for loading" is a status in which the delivery vehicle **50** is traveling to the position in which it loads goods (articles). "Traveling for unloading" is a status in which the delivery vehicle **50** is traveling to the position in which it unloads goods. "Traveling" is a status in which the delivery vehicle **50** is traveling for a purpose other than the transfer of goods, such as dispatch, push-out, or circulation. "Loading" is a status in which the delivery vehicle **50** is raising the lifting apparatus thereof after lowering it and causing a gripper to grasp goods, for example, on the load port of a production facility below the rail. "Unloading" is a status in which the delivery vehicle **50** is raising the lifting apparatus after lowering it and placing goods grasped by the gripper, for example, on the load port of a production facility below the rail.

The status "abnormal/warning" has manual, automatic, and semi-automatic modes. The statuses other than "abnormal/warning" have automatic and semi-automatic modes. For example, the status "traveling" includes "traveling automatically," whose mode is automatic, and "traveling semi-automatically," whose mode is semi-automatic. Similarly, the status "loading" includes "loading automatically," whose mode is automatic and "loading semi-automatically," whose mode is semi-automatic. The same applies to the other statuses.

While the delivery vehicle **50** preferably has the multiple statuses (operating statuses) as described above, the required amount of power varies among the statuses. For this reason, in the present preferred embodiment, the power controller **32** of the vehicle controller **10** assigns the delivery vehicles **50** the main amount of power which is able to be supplied to the feeding areas **20**A and **20**B with optimal allocation corresponding to the operating statuses of the delivery vehicles **50**. The respective delivery vehicles **50** perform operations requested by commands within the assigned maximum amounts of power consumption.

FIG. **6** is a block diagram showing the configuration of a delivery vehicle shown in FIG. **1**. It is assumed that the delivery vehicle **50** shown in FIG. **6** is a delivery vehicle in the feeding area **20**A (e.g., one of the delivery vehicles **50**A to **50**D shown in FIG. **2**). Further, in the present preferred

embodiment, it is assumed that the delivery vehicles **50** preferably have the same configuration. As shown in FIG. **6**, the delivery vehicle **50** includes a communicator **100**, a traveling controller **110**, a raise/lower controller **130**, a transfer controller **150**, servo systems **120**, **140**, and **160**, a power supply controller **170**, and a power receiving coil **171**.

The traveling controller **110**, raise/lower controller **130**, and transfer controller **150** constitute the operation controller **53** shown in FIG. **3**. The communicator **100**, operation controller **53** (traveling controller **110**, raise/lower controller **130**, and transfer controller **150**), and servo systems **120**, **140**, and **160** constitute a servomechanism.

The communicator **100** is a processor that receives command information from the vehicle controller **10** and transmits status report information to the vehicle controller **10**. The communicator **100** transmits or receives information to or from the vehicle controller **10** in communication cycles of, for example, 100 ms. The communicator **100** serves as the operation information transmitter **51** and power amount information receiver **52** shown in FIG. **3**.

The traveling controller **110** controls the traveling of the delivery vehicle **50** by transmitting a command to the servo system **120** to drive a servomotor (see FIG. **8**) in the servo system **120**. The traveling controller **110** also transmits status report information (status information, current position information, inter-vehicle distance information) corresponding to the current operating status of the delivery vehicle **50** through the communicator **100**.

The raise/lower controller **130** controls the raising or lowering of a platform (not shown) mounted on the delivery vehicle **50** by transmitting a command to the servo system **140** to drive a servomotor (not shown) in the servo system **140**. The raise/lower controller **130** also transmits status report information (mainly, status information) corresponding to the current operating status of the platform through the communicator **100**.

The transfer controller **150** causes a gripper (not shown) mounted on the platform of the delivery vehicle **50** to grip or release goods by transmitting a command to the servo system **160** to drive a servomotor (not shown) in the servo system **160**. The transfer controller **150** also transmits status report information (mainly, status information) corresponding to the current operating status of the transfer apparatus through the communicator **100**.

The power supply controller **170** and power receiving coil **171** constitute a non-contact power receiving apparatus of the delivery vehicle **50**. A guide wire (also called a feeder line) installed along the rail **60** (see FIG. **2**) and a feeder panel that converts commercial power into power having a predetermined frequency suitable for non-contact power supply and transmits the power to the guide wire constitute a non-contact power supply apparatus **70** shown in FIG. **6**. When the feeder panel transmits the power having the predetermined frequency to the guide wire, a magnetic field occurs around the guide wire. The power receiving coil **171** is disposed in a position opposite to the guide wire in the delivery vehicle **50** and receives the power through the magnetic field generated by the guide wire. The power supply controller **170** stabilizes the power received by the power receiving coil **171** and supplies the resulting power to the servo systems **120**, **140**, and **160**.

While the vehicle controller **10** and delivery vehicles **50** are able to communicate with each other as described above, the delivery vehicles **50** are also able to communicate with one another.

Next, the operation of the vehicle control system **1** according to various preferred embodiments of the present invention will be described.

FIG. **7** is a flowchart showing an example of a power control process performed by the vehicle controller. In the description of FIG. **7**, it is assumed that the vehicle controller **10** performs a power control process. In the power control process shown in FIG. **7**, the power controller **32** of the vehicle controller **10** acquires suppliable power information and feeding area information. The power controller **32** also receives status report information transmitted from all the delivery vehicles, **50**A to **50**D, in the feeding area **20**A through the communicator **33**. The power controller **32** also acquires area entry information. In this way, the power controller **32** acquires the suppliable power information, feeding area information, status report information, and area entry information (step S**1**).

The power controller **32** then recognizes the main amount of power that is able to be supplied to the feeding area **20**A, based on the suppliable power information and feeding area information. The power controller **32** also recognizes the statuses (operating statuses) and number of the delivery vehicles **50**A to **50**D based on the status report information. The power controller **32** also recognizes whether there are any delivery vehicles which are newly entering the feeding area **20**A, based on the area entry information.

Next, the vehicles number controller **32**A of the power controller **32** determines the number of the delivery vehicles in the feeding area **20**A based on the recognized main amount of power, the statuses of the delivery vehicles **50**A to **50**D (if there are any newly entering delivery vehicles, the statuses of those delivery vehicles), the number of the delivery vehicles **50**A to **50**D, and information indicating whether there are any delivery vehicles entering the feeding area **20**A (step S**2**).

Specifically, the vehicles number controller **32**A of the power controller **32** determines the number of delivery vehicles in the feeding area **20**A using the following method. That is, the vehicles number controller **32**A determines whether there are any delivery vehicles which are newly entering the feeding area **20**A, based on the area entry information; if the vehicles number controller **32**A determines that there are no newly entering delivery vehicles, it grasps the number of the delivery vehicles **50**A to **50**D currently present in the feeding area **20**A (four in the example shown in FIG. **2**) as the number of delivery vehicles; and if the vehicles number controller **32**A determines that there are any newly entering delivery vehicles, it adds the number of the delivery vehicles newly entering the feeding area **20**A to the number of the delivery vehicles **50**A to **50**D currently present in the feeding area **20**A and grasps the resulting number as the number of delivery vehicles. The vehicles number controller **32**A then checks the statuses (operating statuses) of all the delivery vehicles grasped as the number of delivery vehicles. The vehicles number controller **32**A also checks the minimum guarantee amounts of power corresponding to the statuses of all the delivery vehicles. As used herein, the minimum guarantee amount of power refers to the minimum amount of power which the delivery vehicle requires to perform an operation corresponding to the status thereof and which should be guaranteed.

The vehicles number controller **32**A then determines whether a total minimum guarantee amount of power obtained by summing up the minimum guarantee amounts of power corresponding to the statuses of all the delivery vehicles exceeds the main amount of power that can be supplied to the feeding area **20**A. If the total minimum guarantee amount of power does not exceed the main amount of power,

the vehicles number controller **32**A permits the new delivery vehicles to enter the feeding area **20**A. In contrast, if the total minimum guarantee amount of power exceeds the main amount of power, the vehicles number controller **32**A refuses (restricts) the entry of the new delivery vehicles into the feeding area **20**A.

If the vehicles number controller **32**A of the power controller **32** refuses the entry of those delivery vehicles into the feeding area **20**A in step S**2**, it outputs the result. The vehicle controller **10** receives the result and places those delivery vehicles on standby or performs a process such as the change of the route.

Subsequently, based on the number and statuses of the delivery vehicles determined in step S**2**, the power amount assigner **32**B of the power controller **32** determines the power limit values (maximum amounts of power consumption) of the delivery vehicles (step S**3**). Specifically, the power amount assigner **32**B determines standard amounts of power corresponding to the statuses of all the delivery vehicles determined in step S**2** as the power limit values of those delivery vehicles. As used herein, the standard amount of power refers to a sufficient amount of power to perform an operation corresponding to the status.

The power amount assigner **32**B then determines whether a total standard amount of power obtained by summing up the standard amounts of power corresponding to the statuses of all the delivery vehicles exceeds the main amount of power that is able to be supplied to the feeding area **20**A. If the total standard amount of power exceeds the main amount of power, the power amount assigner **32**B sets power limit values to all the delivery vehicles in such a manner that the sum of the power limit values of all the delivery vehicles falls within the main amount of power and in such a manner that the power limit value of at least one of all the delivery vehicles does not fall below the corresponding minimum guarantee amount of power, based on predetermined priorities assigned to the statuses. Higher priorities are assigned to more important statuses in order to efficiently perform delivery tasks corresponding to delivery requests. For example, the power amount assigner **32**B sets, to a delivery vehicle whose status has the highest priority, the standard amount of power thereof as the power limit value and sets, to a delivery vehicle whose status has a low priority, the amount of power which is smaller than the corresponding standard amount of power but does not fall below the corresponding minimum guarantee amount of power as the power limit value.

Subsequently, the power controller **32** outputs the power limit values of the delivery vehicles determined in step S**3** to the communicator **33**. The communicator **33** sets the power limit values in transmission buffers corresponding to the respective delivery vehicles (step S**4**). The communicator **33** then transmits command information including the power limit value information to the delivery vehicles in synchronization with the communication cycles.

In step S**3** described above, if the sum of the standard amounts of power exceeds the main amount of power, the power controller **32** sets power limit values to all the delivery vehicles based on the predetermined priorities assigned to the statuses, but it is not limited such a configuration. For example, the power controller **32** may set power limit values to all the delivery vehicles so that the sum of the power limit values of all the delivery vehicles falls within the main amount of power, by uniformly reducing, from the respective standard amounts of power of all the delivery vehicles, the amount of power obtained by dividing, by the number of all the delivery vehicles, the amount of power by which the sum of the standard amounts of power exceeds the main amount of power.

The power control by the vehicle controller **10** described with reference to FIG. **7** produces the following advantageous effects. That is, the power controller **32** assigns, to the delivery vehicles **50**, available amounts of power corresponding to the statuses (operating statuses) thereof within the main amount of power, and the delivery vehicles **50** perform predetermined operations within the respective assigned amounts of power. That is, the power controller **32** assigns, to the delivery vehicles **50**, the amounts of power most suitable for the statuses thereof within the main amount of power available to the system. Thus, it is possible to increase the number of delivery vehicles **50** that are able to be driven and thus to improve delivery efficiency. Further, since the main amount of power that is able to be supplied to the vehicle control system **1** is used efficiently, the main amount of power is significantly reduced.

Further, since each delivery vehicle **50** transmits status information about the current operation thereof to the vehicle controller **10** in predetermined cycles, the vehicle controller **10** is able to change the amount of power assigned to the delivery vehicle **50** in accordance with the operation thereof when necessary. Thus, a robust system is provided. Further, in the case that the power controller **32** assigns the amounts of power to the delivery vehicles **50** based on the priorities of the operations of the delivery vehicles **50**, the power controller **32** is able to assign a sufficient amount of power to a delivery vehicle **50** which is performing an important operation in a delivery task. As a result, a reduction in the efficiency of the delivery task is avoided. Further, in the case that the power controller **32** assigns to each delivery vehicle **50**, the amount of power that does not fall below the corresponding minimum guarantee amount of power, which allows the delivery vehicle **50** to perform a predetermined operation, the power controller **32** prevents the delivery vehicles **50** from lacking power.

Further, if the area in which the delivery vehicles **50** are able to move is divided into multiple feeding areas, **20**A and **20**B, and if the system includes a vehicle controller **10** that assigns the suitable main amounts of power to the feeding areas **20**A and **20**B, it is possible to improve the power efficiency of the entire system, which is divided into the multiple areas, **20**A and **20**B. Further, when a delivery vehicle from one of the feeding areas **20**A and **20**B enters the other feeding area, if the amount of power assigned by the power controller **32**, of at least one of the delivery vehicles **50** in the other feeding area falls below the corresponding guaranteed minimum amount, which allows the delivery vehicle **50** to perform a predetermined operation, the vehicle controller **10** restricts the entry of the delivery vehicle into the other feeding area. As a result of the configuration described above, it is possible to reliably drive the delivery vehicles **50** in the feeding areas managed by the vehicle controller.

FIG. **8** is a block diagram showing the configurations of the traveling controller and servo system. The elements shown in FIG. **8** are implemented when an arithmetic device such as a CPU performs processing in accordance with a program stored in the memory.

The traveling controller **110** includes a command generator **111**, a torque limit value calculator **112**, and an acceptable value calculator **113**. The command generator **111** includes a command position generator **111***a*, an acceptable value determiner **111***b*, and a command position changer **111***c*. The command position generator **111***a* of the command generator **111** receives command information transmitted from the vehicle controller **10** through the communicator **100**. Then,

based on operation command information and inter-vehicle distance control command information included in the command information, the command position generator **111***a* generates an operation waveform to cause the delivery vehicle **50** to perform an operation (traveling) indicated by the operation command information at a position and speed indicated by the inter-vehicle distance control command information.

The command position generator **111***a* of the command generator **111** then generates a command position (the amount of rotation, rotation angle) of a servomotor **122** of the servo system **120** based on the generated operation waveform. The command position generator **111***a* then outputs the generated command position to a servo amplifier **121** of the servo system **120**, as well as to the acceptable value calculator **113**. The command position here is a pulse signal. The position (the amount of rotation, rotation angle) of the servomotor **122** with respect to one pulse is predetermined. The pulse frequency serves as the speed (the number of revolutions, rotation speed) of the servomotor **122**.

The acceptable value determiner **111***b* of the command generator **111** determines whether to change the position commanded to the servo amplifier **121** by the command position signal (hereafter referred to as the command position), based on a command acceptable value (to be discussed later) outputted from the acceptable value calculator **113**. In the present preferred embodiment, if the acceptable value determiner **111***b* determines that the command position generated by the command position generator **111***a* based on the operation waveform (the command position generated based on the command information from the vehicle controller **10**) exceeds the command acceptable value, it determines that the command position is to be changed to the command acceptable value. When the acceptable value determiner **111***b* determines that the command position to be changed, the command position changer **111***c* of the command generator **111** changes the command position to the command acceptable value and outputs the changed command position to the servo amplifier **121** of the servo system **120**.

The torque limit value calculator **112** receives the power limit value (power amount information) included in the command information transmitted from the vehicle controller **10**. The torque limit value calculator **112** also receives the current speed of the servomotor **122** fed back from the servo amplifier **121** (hereafter referred to as the "FB speed"). The torque limit value calculator **112** then calculates a torque limit value to limit the maximum torque of the servomotor **122** based on the FB speed from the servomotor **122** and the power limit value (maximum power consumption) indicated by the power amount information and outputs the calculated torque limit value to the servo amplifier **121**.

The acceptable value calculator **113** receives the current position of the servomotor **122** fed back from a position detector **122**A disposed in the servomotor **122** (hereafter referred to as the "FB position"). Then, based on the FB position, the acceptable value calculator **113** calculates a command acceptable value, which is acceptable as a command position that the FB position should follow. The acceptable value calculator **113** then outputs the calculated command acceptable value to the command generator **111**.

The servo system **120** includes the servo amplifier (drive controller) **121** and servomotor **122**. The servo amplifier **121** calculates a deviation (difference) of the FB position (pulse signal) outputted by the position detector **122**A of the servomotor **122** from the command position outputted by the command generator **111** using a deviation counter. The servo amplifier **121** then controls the drive of the servomotor **122** by supplying a drive current corresponding to the deviation calculated using the deviation counter to the servomotor **122**. At this time, the servo amplifier **121** controls the drive current to drive the servomotor **122** so that the torque of the servomotor **122** does not exceed the torque limit value outputted from the torque limit value calculator **112**. The servo amplifier **121** also converts the FB position outputted from the position detector **122**A into a FB speed and outputs the FB speed to the torque limit value calculator **112**.

The servomotor **122** is a motor that is driven (rotationally driven) based on the drive current supplied from the servo amplifier **121**. The servomotor **122** includes the position detector **122**A, which detects the position (the amount of rotation) of the servomotor **122**. The position detector **122**A consists of, for example, an encoder. However, the position detector **122**A is not limited to an encoder and may be a position sensor such as a laser range finder or magnetic linear sensor. The position detector **122**A outputs the FB position indicating the detected current position of the servomotor **122** to the servo amplifier **121** and the acceptable value calculator **113**.

The traveling controller **110** or command generator **111** includes a processor that outputs the current operating status (status) to the communicator **100**. This also applies to the raise/lower controller **130** and transfer controller **150**. The operation information transmitter **51** of the communicator **100** transmits status report information including operation information to the vehicle controller **10** based on the operating statuses outputted from the traveling controller **110**, raise/lower controller **130**, and transfer controller **150**.

The delivery vehicles **50** must perform operations such as traveling within the respective maximum amounts of power consumption (power limit values) assigned by the vehicle controller **10**. Hereafter, a configuration to limit the torque of the servomotor based on the power limit value will be described.

FIG. **9** is a flowchart showing an example of a power limitation process performed by the traveling controller. The power limitation process shown in FIG. **9** is repeatedly performed in the same cycles as those in which the traveling controller **110** and servo amplifier **121** communicate with each other (e.g., 0.888 ms or 0.444 ms). As shown in FIG. **9**, the torque limit value calculator **112** of the traveling controller **110** receives the power limit value included in the command information transmitted from the vehicle controller **10**. The torque limit value calculator **112** also receives the feedback speed from the servo amplifier **121**. The torque limit value calculator **112** also acquires various parameters preset to the servo system **120**. The various parameters include the efficiency of the traveling driver (servo system **120** and the like) and standby power.

The torque limit value calculator **112** then calculates a torque limit value τ to limit the maximum torque of the servomotor **122**, for example, based on the following formula in which the FB speed of the servomotor **122** and the power limit value (maximum power consumption) indicated by the power limit value information serve as variables (step S**12**).

$$\tau \leq (P-\alpha)/((1/\eta)*(2*\pi/60)*\omega)$$

In this formula, P represents the maximum power consumption (i.e., power limit value) (W); η represents the efficiency of the traveling driver; ω represents the revolutions per minute (rpm) of the servomotor **122**=FB speed (0.01 rpm)/100; τ represents the motor torque (Nm) of the servomotor **122**=(FB torque (0.1%)/10)*1.3 (Nm)/100; and α represents standby power (W).

The torque limit value calculator **112** then outputs (transmits) the calculated torque limit value to the servo amplifier **121** (step S**13**). The communication cycles between the traveling controller **110** and servo amplifier **121** are, for example, 0.888 ms (0.444 ms in some cases). Specifically, the torque limit value calculator **112** sets the torque limit value calculated in step S**12** in a buffer, and transmits the torque limit value set in the buffer to the servo amplifier **121** at the timing synchronous with the communication cycles.

FIG. **10** is a waveform diagram showing the relationships among the power consumption, speed, torque, and torque limit value of the servomotor. In FIG. **10**, the vertical axis represents the amount of power (W), and the horizontal axis represents the time (s). Also, A**1** represents the FB speed (0.1 rpm), A**2** represents the maximum amount of power consumption (power limit value) (0.1 W), A**3** represents the torque limit value (0.1%), A**4** represents the feedback torque (the current torque of the servomotor **122**; "FB torque" in FIG. **10**) (0.1%), and A**5** represents the amount of power consumption (0.1 W) of the servomotor **122**. As shown in FIG. **10**, the maximum amount of power consumption (power limit value) (0.1 W) is set to 1300 W.

The torque limit value calculator **112** calculates a torque limit value A**3** based on the FB speed A**1** and the maximum amount of power consumption A**2**. As shown in FIG. **10**, the servo amplifier **121** controls the FB torque A**4** of the servomotor **122** to a value lower than the torque limit value A**3** by controlling the drive current to drive the servomotor **122**. Thus, the amount of power consumption A**5** of the servomotor **122** is controlled to an amount smaller than or equal to the maximum amount of power consumption A**2** by controlling the FB torque A**4** of the servomotor **122** to the value lower than the torque limit value A**3**.

The torque limitation configuration described using FIGS. **9** and **10** produces the following advantageous effects. That is, since the torque limit value calculator **112** calculates the torque limit value of the servomotor **122** based on the rotation speed of the servomotor **122** and the amount of power consumable by the servo motor **122** and since the servo amplifier **121** drives the servomotor **122** to the extent that the torque of the servomotor **122** does not exceed the torque limit value, it is possible to limit the torque even when disturbance or the like occurs and thus to reduce power consumption. Further, the margin of power consumption in preparation for disturbance or the like is significantly reduced.

Further, by acquiring the rotation speed of the servomotor **122** in predetermined cycles and calculating a torque limit value in the predetermined cycles based on the acquired rotation speed and the amount of power, the torque limit value calculator **112** calculates a torque limit value corresponding to the rotation speed of the servomotor **122** at any time. Further, if the torque limit value calculator **112** receives power amount information transmitted from the vehicle controller **10** and calculates a torque limit value using the received power amount information, the vehicle controller **10** is able to easily change the power consumable by the servo system. Further, if the vehicle controller **10** transmits power amount information to each of the multiple servo systems, it is possible to efficiently use the main amount of power that is available to be supplied to the vehicle control system **1** and thus to reduce the main amount of power.

The servo system **120** controls the drive of the servomotor **122** using a speed and torque corresponding to the distance between the command position and FB position. However, in the present preferred embodiment, the amount of power available to each delivery vehicle **50** is limited to the corresponding power limit value and therefore the torque of the servomotor **122** of the vehicle is controlled to a torque limit value corresponding to the power limit value. Thus, the FB position may fail to follow the command position and deviate therefrom. The FB position may also deviate from the command position due to disturbance. Further, when the FB position excessively deviates from the command position, the servo system **120** may fail to follow the command position, causing a servo error, or may perform an abnormal operation such as abrupt acceleration to follow the command position. For this reason, in the present preferred embodiment, when the FB position deviates from the command position by a predetermined distance or more, the command position is changed in accordance with the FB position. Thus, an excessive deviation of the FB position from the command position is prevented. Hereafter, a configuration to change the command position as described above will be described.

FIG. **11** is a flowchart showing an example of a command value setting process performed by the traveling controller. The command value setting process shown in FIG. **9** is repeatedly performed in the same cycles as those in which the traveling controller **110** and servo amplifier **121** communicate with each other (e.g., 0.888 ms or 0.444 ms). As shown in FIG. **11**, the command position generator **111***a* of the command generator **111** in the traveling controller **110** determines whether the command value setting process is complete (step S**21**). If the command position generator **111***a* determines that the command value setting process is not complete, it determines whether an operation waveform has been generated (step S**22**). If the command position generator **111***a* determines that an operation waveform has been generated, the process proceeds to step S**25**. In contrast, if the command position generator **111***a* determines that any operation waveform has not been generated, it generates an operation waveform (step S**23**). The command position generator **111***a* then generates a command position commanding the position (the amount of rotation) of the servomotor **122** of the servo system **120** based on the generated operation waveform (step S**24**).

The acceptable value calculator **113** receives the FB position from the position detector **122**A in synchronization with the timing when the command position generator **111***a* of the command generator **111** generates the command position. The acceptable value calculator **113** then calculates a command acceptable value using the following formula based on the received FB position (step S**25**). The acceptable value calculator **113** then outputs the calculated command acceptable value to the command generator **111**.

Upper limit of command acceptable value=*FB* position+time integral of command speed+(command speed/position gain)+tolerance (mm)

Lower limit of command acceptable value=*FB* position+time integral of command speed+(command speed/position gain)−tolerance (mm)

In these formulas, the FB position is the current position as described above; and "time integral of command speed" represents the amount (distance) that the delivery vehicle travels at a command speed in a command position signal outputted at this time. Note that the acceptable value calculator **113** is able to recognize the command speed based on the frequency of the command position outputted from the command generator **111**. "Speed command/position gain" represents the amount (distance) corresponding to a delay caused by the position gain. In these formulas, it is assumed that the tolerance is the amount of movement (distance) corresponding to one rotation of the motor.

Since the command value setting process shown in FIG. **11** is performed in the same cycles as the communication cycles,

the command generator **111** generates a command position in the same cycles as the communication cycles, and the acceptable value calculator **113** acquires the FB position in synchronization with the generation of the command position. Thus, the acceptable value calculator **113** is able to calculate a command acceptable value based on the FB position, which is close to the actual current position. Further, since the command acceptable value is set to include the amount of movement of the delivery vehicle **50** during one communication cycle, it is possible to set an accurate command acceptable value.

The acceptable value determiner **111***b* of the command generator **111** determines whether the command position generated based on the operation waveform exceeds the command acceptable value (step S**26**). If the acceptable value determiner **111***b* determines that the command position does not exceed the command acceptable value, the command position changer **111***c* of the command generator **111** outputs (transmits) the command position generated based on the operation waveform to the servo amplifier **121** without changing the command position (step S**27**). In contrast, if the acceptable value determiner **111***b* determines that the command position exceeds the command acceptable value, the command position changer **111***c* of the command generator **111** changes the command position generated based on the operation waveform to the command acceptable value. As seen above, since the command generator **111** is able to change the command position to the command acceptable value at the timing when the command position is generated, it is possible to prevent a delay in changing the command position and to control the drive of the servomotor **122** based on the changed command position. The command generator **111** then outputs (transmits) the command position representing the command acceptable value ("the command acceptable value" in FIG. **11**) to the servo amplifier **121** (step S**28**).

As described above, the traveling controller **110** and servo amplifier **121** communicate with each other in cycles of 0.888 ms, for example. Accordingly, in the transmission processes of steps S**27** and S**28**, the command generator **111** sets the command position signal in the buffer and transmits the command position signal set in the buffer to the servo amplifier **121** at the timing synchronous with the communication cycles.

FIG. **12** is a diagram showing waveforms of the unchanged command position, the current position, and the changed command position. In FIG. **12**, the vertical axis represents the distance from a predetermined position (mm), and the horizontal axis represents the time (s). B**1** represents the command position generated based on an operation waveform; B**2** represents the FB position; and B**3** represents the command position changed by the command generator **111**, that is, the command acceptable value.

As shown in FIG. **12**, at time t**1**, that is, immediately after the servomotor **122** starts to operate at a predetermined speed, the FB position B**2** has yet to deviate from the command position B**1**. However, from time t**2** onward, the FB position B**2** gradually deviates from the command position B**1** due to the limitation of the torque based on the torque limit value, disturbance, or the like. At time t**3**, the command position B**1** becomes the command acceptable value B**3** or more. At this time, the command generator **111** changes the command position B**1** to the command acceptable value B**3** and outputs the changed command position to the servo amplifier **121**. Thus, a deviation of the FB position B**2** from the command position (command acceptable value B**3**) by a predetermined distance or more is prevented. At time t**4**, the servomotor **122** is driven at an increased speed owing to the relaxation of the power limit value or the disappearance of disturbance and thus the FB position B**2** comes close to the command position B**1**. Subsequently, at time t**5**, the servomotor **122** comes to a stop, and the FB position B**2** reaches the command position B**1**.

While the limitation of the torque and the change of the command position performed by the traveling controller **110** and servo system **120** have been described with reference to FIGS. **8** to **12**, the raise/lower controller **130** and servo system **140**, or the transfer controller **150** and servo system **160** may perform the limitation of the torque and the change of the command position in a similar manner.

Specifically, the raise/lower controller **130** may also include the same or approximately the same elements as the command generator **111**, the torque limit value calculator **112**, and the acceptable value calculator **113** of the traveling controller **110** and perform the processes shown in FIGS. **9** and **11**. More specifically, the torque limit value calculator of the raise/lower controller **130** calculates a torque limit value based on the power amount information and the FB speed from the servo amplifier; the servo amplifier limits the torque of the servomotor within the torque limited by the torque limit value calculated by the torque limit value calculator and drives the lifting apparatus; the acceptable value calculator of the raise/lower controller **130** calculates a command acceptable value based on the FB position outputted from the position detector; the acceptable value determiner of the command generator determines whether the command position exceeds the command acceptable value; and if the acceptable value determiner determines that the command position exceeds the command acceptable value, the command position changer of the command generator changes the command position to the command acceptable value.

The transfer controller **150** may also include the same or approximately the same elements as the command generator **111**, the torque limit value calculator **112**, and the acceptable value calculator **113** of the traveling controller **110** and perform the processes shown in FIGS. **9** and **11**. More specifically, the torque limit value calculator of the transfer controller **150** calculates a torque limit value based on the power amount information and the FB speed from the servo amplifier; the servo amplifier limits the torque of the servomotor within the torque limited by the torque limit value calculated by the torque limit value calculator and drives the transfer apparatus; the acceptable value calculator of the transfer controller **150** calculates a command acceptable value based on the FB position outputted from the position detector; the acceptable value determiner of the command generator determines whether the command position exceeds the command acceptable value; and if the acceptable value determiner determines that the command position exceeds the command acceptable value, the command position changer of the command generator changes the command position to the command acceptable value.

As described above, in the present preferred embodiment, the acceptable value calculator **113** calculates a command acceptable value based on the current position of the delivery vehicle **50**; the acceptable value determiner **111***b* of the command generator **111** determines whether the command position exceeds the command acceptable value; and if the command position is determined to exceed the command acceptable value, the command position changer **111***c* of the command generator **111** changes the command position. Thus, it is possible to prevent the current position from deviating from the command position due to unexpected disturbance, the limitation of the amount of power, or the like. As a result, the following are prevented: a significant deviation of

the current position from the command position and thus a failure to follow the command position; the raising of the output torque to follow the command position and thus an increase in power consumption; and the impairment of safety due to an excessive movement.

Further, if the delivery vehicle **50** includes a position detector **122**A that detects the current position thereof and the acceptable value calculator **113** calculates a command acceptable value based on the current position outputted from the position detector **122**A, it is possible to calculate a command acceptable value based on the correct current position. Further, if the command position changer **111***c* of the command generator **111** changes the command position to the command acceptable value or a predetermined position within a range which does not exceed the command acceptable value, it is possible to set the command position to a command acceptable value corresponding to the form or the use form of the servo system. Further, if the command position generator **111***a* of the command generator **111** generates a command position in predetermined cycles and if the acceptable value calculator **113** acquires the current position in synchronization with the generation of the command position, it is possible to calculate a command acceptable value based on the position information, which is close to the actual current position. Further, if the command acceptable value is set to include the amount of movement of the delivery vehicle **50** during one cycle of process cycles same as the communication cycles, it is possible to set an accurate command acceptable value. Further, if the command position changer **111***a* changes the command position at the timing when the command position generator **111***a* generates the command position, it is possible to prevent a delay in changing the command position and to control the drive of the servomotor **122** based on the changed command position.

While preferred embodiments of the present invention have been described, the present invention is not limited to the elements and the like shown in the drawings. Changes can be made to the elements and the like without departing from the functions, purposes, and the like thereof. While the area in which the delivery vehicles **50** are able to move is preferably divided into the two feeding areas, **20**A and **20**B, in the above embodiment, the area may be divided into three or more feeding areas, for example.

While the respective feeding areas preferably correspond to the same system in the above preferred embodiments, the feeding areas may correspond to different systems. For example, one feeding area may correspond to a system using a stacker crane, and the other feeding area may correspond to a system using a ceiling traveling vehicle or the like, which differs from a stacker crane.

While, in the above preferred embodiments, the feeding areas are areas in which there are installed production facilities and the like for which delivery vehicles **50** actually perform delivery tasks, there may be an area in which multiple delivery vehicles **50** are placed on standby (standby area). In this case, the delivery vehicles **50** are dispatched from this standby area to a feeding area. Since the delivery vehicles **50** in this standby area need power to perform operations such as traveling, the standby area is also assigned the main amount of power.

The following configuration may also be used: video or images of the operating statuses of the delivery vehicles **50** is captured using an imaging device such as a video camera; the operating statuses of the delivery vehicles **50** are analyzed based on the video or images using a method such as pattern matching; and the vehicle controller **10** acquires the analysis results as operation information.

While the torque limit value calculator **112** is included in the traveling controller **110** in the above preferred embodiments of the present invention, it may be included in the servo amplifier **121**.

While the command position is changed to the command acceptable value in the above preferred embodiments of the present invention, the command position may be changed to a position which prevents the servo system **120** from failing to follow the command position and thus causing a servo error or prevents the servo system **120** from performing an abnormal operation such as abrupt acceleration to follow the command position. Accordingly, the command position may be changed to a predetermined position within a range which does not exceed the command acceptable value.

While, in the above preferred embodiments, the upper and lower limits of the command acceptable value preferably are calculated using the formulas: upper limit of command acceptable value=FB position+time integral of command speed+(command speed/position gain)+tolerance (mm), and lower limit of command acceptable value=FB position+time integral of command speed+(command speed/position gain)−tolerance (mm). However, such a calculation is merely one non-limiting example, the command acceptable value may be calculated as a position which prevents the servo system **120** from failing to follow the command position and thus causing a servo error or prevents the servo system **120** from performing an abnormal operation such as abrupt acceleration to follow the command position.

While it is assumed in the above preferred embodiments that the non-contact feeding system preferably is an electromagnetic induction-type system, the system may be an electromagnetic resonance-type system, which uses a resonance phenomenon of an electromagnetic field. The system may also be a contact-type feeding system using a trolley or the like.

While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing from the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

The invention claimed is:

1. A delivery vehicle comprising:

a command position generator that generates a command position to move the delivery vehicle to a target position by driving a servomotor;

an acceptable value calculator that calculates a predetermined acceptable value based on a current position;

an acceptable value determiner that determines whether the command position exceeds the predetermined acceptable value calculated by the acceptable value calculator; and

a command position changer that changes the command position when the acceptable value determiner determines that the command position exceeds the predetermined acceptable value.

2. The delivery vehicle of claim **1**, further comprising a position detector configured to detect the current position, wherein the acceptable value calculator calculates the predetermined acceptable value based on the current position outputted from the position detector.

3. The delivery vehicle of claim **1**, wherein the command position changer changes the command position to the predetermined acceptable value or a predetermined position within a range which does not exceed the predetermined acceptable value.

4. The delivery vehicle of claim 1, wherein

the command position generator generates the command position in predetermined cycles; and

the acceptable value calculator acquires the current position in synchronization with generation of the command position.

5. The delivery vehicle of claim 4, wherein the predetermined acceptable value includes the amount of movement during one of the predetermined cycles.

6. The delivery vehicle of claim 1, wherein the command position changer changes the command position at a timing when the command position generator generates the command position.

7. A method to control driving of a delivery vehicle, the method comprising:

generating a command position to move the delivery vehicle to a target position by driving a servomotor;

calculating a predetermined acceptable value based on a current position;

determining whether the command position exceeds the predetermined acceptable value; and

changing the command position when it is determined that the command position exceeds the predetermined acceptable value.

8. A non-transitory computer-readable medium including a computer program that controls driving of a delivery vehicle, the program causing a computer to perform:

generating a command position to move the delivery vehicle to a target position by driving a servomotor;

calculating a predetermined acceptable value based on a current position;

determining whether the command position exceeds the predetermined acceptable value calculated in the acceptable value calculation process; and

changing the command position when it is determined in the acceptable value determination process that the command position exceeds the predetermined acceptable value.

9. The delivery vehicle of claim 1, wherein the command position changer changes the command position so as to advance the command position.

10. The delivery vehicle of claim 1, wherein the command position changer changes the command position to a value calculated by adding at least an amount that the delivery vehicle travels at a command speed to the current position.

11. The delivery vehicle of claim 3, wherein the command position changer changes the command position to a value calculated by adding at least an amount that the delivery vehicle travels at a command speed to the current position and subtracting a tolerance.

* * * * *